PART I.

ANNUAL ADDRESS OF PRESIDENT R. H. WARD.

Dr. Ward was introduced by Dr. Hopkins, and delivered the following address:

MEMBERS OF THE AMERICAN SOCIETY OF MICROSCOPISTS—Since this is a new Society, as yet without a history, a policy, or a thoroughly organized membership, it is believed that an informal address, in a popular form, in regard to the position and objects of our Society will be more timely and useful than such a technical report of original work as would usually be expected in a President's annual address.

The formation of this Society, and the presence of this audience here to-night to welcome its first public meeting, brings us to a contemplation of a branch of science, insignificant in years, trivial in respect to its means and objects of study, but great in its accumulated results, and in its record of influence exerted upon the recent progress of human thought and the development of modern science; a department of learning almost every step in whose progress has been a revolution. It is scarcely more than a hundred years since an enthusiastic friend of the microscope announced certain improvement in the instrument as rendering it "agreeable to the curious." It is within the memory of persons now only in middle age, that a majority of people still considered the instrument merely an elegant toy, that an author who brought one to this country at a cost of $1,000 was derided for his foolish expenditure, and that the high price of superior English instruments was repeatedly and formally stated as the reason of their limited sale in this country—where they are now commended by their cheapness compared with those manufactured here. It is only thirty or forty years since the English opticians, both theoretical and practical, began the development of the really modern microscope, a work in which they were soon aided and sometimes surpassed by their friends in France, Germany, and this country. It is about the same length of time since the brilliant discoveries of Ehrenberg spread abroad from Germany, fascinated the naturalists of England and this country, and taught the whole world the possibilities of the new means of research; yet in those few years an amount of work has been done which it is the labor of a lifetime to review. A dozen years ago the microscope was so complete and satisfactory that some admirers considered it to have reached its limit of practical improvement. One author called it the only perfect instrument, by which it was meant that it was the only instrument of human construction whose performance equaled its theory, whose adaptations to its objects left nothing further to be desired, in whose contrivance

or execution human science had nothing further to ask from human art. Yet every succeeding year must have been a surprise to such an author; the perfect instrument has become more perfect, though it is manifestly faulty still; the stand has been made less clumsy but more steady, less complicated but more convenient, less showy but more durable, less costly but more useful. The objectives have been improved in definition, greatly increased in available aperture, and supplied with far better appliances for cover-adjustment; the immersion system has become universally introduced, its use extended to the means of illumination, and the advantages of a literally homogeneous fluid recognized; the binocular arrangement has grown from an experiment of disputed value to a priceless luxury if not a literal necessity; means of illuminating at definite and known angles have become available; the spectroscope, and the sensitized plate of the photographer, have become powerful accessories; and the instrument of which that proud remark was so lately made, has already become obsolete and grotesque, one of the curiosities of history rather than an instrument of precision well fitted for delicate scientific work.

Still more recent and sudden has been the evolution of our extensive system of microscopical *societies*. Of our thirty societies, many have been formed during the last two years, a large number originated in 1874 and thereafter, and scarcely two or three outdate the origin of our Troy society in 1870. As late as 1874, when I first collected those particulars in regard to the societies which were published early in 1875, so little public attention had the movement commanded that data in regard to them were collected with much difficulty and delay. Many of the older organizations are still strong and active, and many of the newer bodies are now large, and energetic, and full of life; and I hope that one of the direct results of the foundation of this general Society will be the birth of new local associations in those centers of scientific culture where they are still wanting. (Perhaps this cause may be believed to have had something to do with the new arrival in Detroit within the last few days.) Residents at those localities should not hesitate from want of experience or doubt of success; but should consider the present time the best time, and act accordingly. It is easy to row with the tide, and the tide sets that way. Microscopy is in favor now, and societies are popular, and some of the newest of them have already surpassed in size the eldest. It is not requisite to affect much learning, incur much expense, or wait for the support of a crowd. In any community, however unscientific, where there are a few persons so intelligently interested in the microscope as to use it with advantage, and sufficiently homogeneous to take pleasure in associating together, if those persons will but meet together, with their instruments, statedly and systematically, for such work in this department as may correspond with their tastes and qualifications, the formation of the society, whatever they may call it, will not only be possible but actually accomplished; and if they will take the trouble to interest and encourage beginners, and without arrogance or clannishness, to make welcome as members all who are likely to be really useful, the work of building up the society will thereafter take care of itself. How often such a society should meet will depend upon the amount of leisure, and of scientific and literary activity of its members. A few good meetings are far better than many poor ones; yet too long intervals tire out the enthusiasm of the participants. The experience of our American cities seems to teach that meetings should usually be held either once or twice a month. How far the society should be popularized, how formal should be its meetings, and how dis-

tinctly literary its proceedings, how prominent a place should be given to the mere exhibition of instruments and objects, and how freely, if at all, intelligent persons not especially cultivating this branch of science should be made welcome as visitors, will depend almost entirely upon local considerations, which can be best judged by those who are familiar with the ground, especially by any who have the advantage of experience in the organization and direction of affairs. It may be said, however, that it is safer, as well as more generous, to err on the side of liberality than of exclusiveness; that such societies, like plants, are very likely to grow best in the light; and that science can be best cultivated by the few when it is best understood and appreciated by the many. It should also be remembered that a scientific society or club is not a school to be drilled by one or two pedagogues, nor a lecture association to be regularly addressed, from above, by a few professional lecturers, still less by the same number of amateur instructors, but a body of members affiliated by community of tastes and purposes, who meet on an equal platform for mutual work. Of course, they will recognize as leaders those among them whose intellectual discipline and experience in affairs would render them indispensable as guides; but they will be induced, unless those leaders prove wanting in judgment or in tact, to feel an active interest and mutual responsibility in the work of the society, whatever that may be. And the standard of work in the society, even though it should therefore be less formal or intellectual than would please a few, should not be set too high to secure the free and somewhat equal participation of the membership generally. The members, if intelligent, will appreciate wisdom and experience, and the power to direct, none the less because it takes the form of an associate and not of a director; and the leaders can afford to be generous if they are qualified to be at the head.

It is as easy to found a general as a local society, but not so easy to secure its permanence. Our infant society, the first anniversary of whose birthday we celebrate to-night, begins its life at a time most fortunate. Never before could it have been born with half the present chance of life. The favoring circumstances seem strong, and the hindrances those only that are inherent in the circumstances amid which it must live, if live it can at all. We enter the field with courage and enthusiasm. Succcess seems to be simultaneous with effort. The first meeting was equal to our hopes; the second surpasses the first. But we must realize that the magnitude of the project involves the most serious responsibilities. To justify its name an American society must *be* American; it must be neither meagre nor local; it must have a large, active and permanent membership, well distributed among the various sections of the country; it must include names of recognized ability and influence, and must be really representative of American microscopy; it must be a power as well as a name. To make it feeble would be a failure, to make it local would be a farce. Yet the obstacles in the way of success are such as might well check any faith, but the enthusiasm of youth. Distances are great in this country, and not all men of science are men of wealth or of leisure. Many persons of distinguished qualifications for membership have written, this year, that distances are too great, and that the time and expense involved will prevent their participation. When I remarked to a London friend, at Philadelphia, during the centennial summer, that I should be at the meeting of the American Association for the Advancement of Science in this city the next morning, adding that the plan of meeting so near was favorable as it enabled members both to attend the meeting and to visit the exhibition at Philadelphia during the same trip, he looked

puzzled, and replied that he did not think Buffalo near, they would consider it a great way off in England. Furthermore, it is well known that some who can give the time to attend distant meetings, have other plans which, unless they can be harmonized, will stand more or less in the way of this. The practical questions, then, of how often these meetings should be held, and over what range of territory, and by what means a steady and adequate attendance can be maintained after the attraction of novelty has ceased to act, and the tax upon time, and thought, and money has become felt, should receive the most serious and deliberate consideration, and all the aid that can be derived from the experience of others, in order that our plans may be wise and our success permanent.

The interruption to the *mailing of slides* on account of legal technicalities, which has been a subject of prominent interest during the past year, has just reached a satisfactory settlement, of which it is a pleasure to now make the first public announcement. The old law forbade mailing glass, or objects packed in glass; and as applied to the objects for which it was intended, its wisdom was not questioned. Probably its authors never thought of the little subject of microscopical slides and the inconvenience to scientific students which would result from interruption to their transit through the mails. It was evident from the first that difficulty might possibly arise by literal enforcement of the law, and that relief must be sought from Congress and not from the Post Office Department. It needed no official decision to establish the fact that glass slides were made of glass, and an appeal to the Department could only compel them to obstruct a privilege which had always been practically enjoyed without thought of conflict with the spirit or intention of the law, and without a single complaint of injury done or feared. When the American Postal Microscopical Club, (originally named Micro-cabinet Club), was organized for the purpose of cultivating microscopical science by interchange of written communications and of objects through the mails, and with a membership distributed throughout the United States, its officers brought this subject before prominent members of Congress and received assurances that the interests of science should not be overlooked, and that the desired objects could doubtless be attained without objection when the postal laws should next be revised. As yet no inconvenience, save occasionally a local and trivial one, was experienced, as the post offices generally allowed the slides to pass without fear or question. But during the last winter public agitation produced the inevitable result of forcing an application of the law to this case, of rendering the mailing of slides improper and impracticable, and of abruptly suspending the operations of the Postal Club. Meanwhile a new postal law has been prepared and is now in force. At the request of scientific men, and without objection, a clause was inserted in that bill, allowing the Postmaster-General to decide without constraint in regard to the safety of such postal matter. It was supposed by many that this settled the difficulty at once; but the new regulations, made public three months ago, required objects packed in glass to be contained, for double security, in a suitable case which should be itself inclosed in an outer case of metal or hard wood. Some further delay was experienced in obtaining a case which should fulfill these conditions to the satisfaction of the Department, and without too much expense or weight to answer our purposes. A package just received from Washington, and which meets the approval of the Department, will show a perfectly feasible manner of packing slides for mailing, with the certainty of official approval at headquarters. This box is wrapped in a strip of thin sheet brass or tin,

which may be used an indefinite number of times. The added weight and expense are not large and the trouble not greater than that from paper wrappers. The inner case, in this instance, is the regular box lately exclusively used by the Postal Club. It is like the common racked boxes except that it is packed with cloth in the manner devised by myself two years ago, every part of the slide, except the center where the cover-glass is situated, being supported by a thick layer of soft cloth. Since the introduction of this method the loss of slides by cracking has become almost unknown. As a result of this adjustment of the postal difficulty, steps are now being taken for the immediate revival of the Postal Club. [Box shown.]

One of the most important questions, theoretical and practical combined, which is now fairly before the microscopical world and still in an unsettled state, is that of gaining definiteness and uniformity in *micrometry*. In this field emergencies have arisen during the past year which have compelled me to take considerable responsibility, as well as to perform a large amount of work, trusting that the generous approval of my colleagues would accept and ratify what seemed at the time and what seems now most consistent with the interests of science and the dignity of this body. It will be remembered that a year ago, just at the close of our Indianapolis meeting, resolutions were offered favoring the adoption of the metric system for micrometry, and the one hundredth millimetre as the unit to be employed, inviting foreign co-operation, and accepting an offer of standard micrometers from Prof. William A. Rogers, of the Astronomical Observatory of Harvard University. None of these points, save the last, were new or unconsidered. They had been studied at leisure for years by many members who were present. The metric system has been adopted by all the civilized world except Russia, England and the United States; and its universal adoption was, as a rule, earnestly desired and favored by the educated and scientific classes. It has been adopted, or recommended, after mature deliberation, by the National Academy of Sciences, the American Metrological Society, the American Association for the Advancement of Science, by the American Society of Civil Engineers, the United States Coast Survey, the United States Marine Hospital Service, the American Medical Association, the Congress of Ophthalmologists, and by the largest State and local Medical Societies and by leading Medical Schools and Journals, by numerous Boards of Education, College Faculties and local Scientific Societies, and by experts in various branches of science and art. On the other hand the resolutions contained some minor faults, mostly in matters of taste or tact, which could have been easily remedied by reference to a committee. But there was no time for reference or for adequate discussion, and rather than discourage their object by failure or postponement, they were adopted and referred to the local Societies for consideration. They were passed unanimously, at a small session, it is true, but by the same vote which established this society and authorized its meeting here to-day. As too often happens, their incidental faults attracted more attention than their really scientific object. The unit proposed was evidently too long for integers and too short for fractions, and unlikely to receive a single approval either at home or abroad; the proposal of international action, though its object was universally approved, was in a form not likely to accomplish that object; and the liberal offer of Prof. Rogers was wholly misunderstood and perverted, until it took the form of the preposterous statement that it was proposed to make Prof. Rogers' micrometers standard as distinguished from those of other (!) makers, not the least amusing of all the

blunders and absurdities of this precious statement being the association, in any manner, of trade rivalry or mercenary considerations with the work of one of our most generous scientists who has freely shared with the public every result of his labors, while pursuing them at an extravagant cost, and without a thought of pecuniary return. It soon became evident that an organized treatment of the subject was required to secure a proper and unprejudiced discussion of the objects of the resolutions. Feeling much responsibility as the presiding officer of this Society, and of one of the oldest of the local Societies, but having no authority to appoint an evidently necessary committee that should represent not only this Society but also sections of the country not yet named upon our rolls, I brought the subject before our local Association, and we invited all the Societies that could be reached to join with us in the selection of a National Committee for the consideration of this this subject. The response from the large and active Societies, and from distinguished individuals, was a cordial and almost unanimous approval. Many of the Societies nominated to the committee members distinguished as specialists in this branch of microscopy; both Societies and eminent scientists contributed valuable opinions upon all the points at issue; and a large committee was organized which will, at a proper time, tender a report of progress to this Society. And while speaking of this committee, I will take the liberty of saying that it would be a pleasure to me, and I doubt not to all of us on this side of the Lakes, if our friends from Toronto or Montreal, or any other points in the Dominion which may be represented here, would nominate members, and thus make it an American instead of a national body. To prevent confusion or misapplication of the practical suggestions which follow, and which naturally belong to this time and place, it is necessary to anticipate the report of the committee so far as to say that it will recommend to this Society to rescind its approval of the 1-100th millimeter as the unit of micrometry, and to so modify the forms of the other resolutions as to leave the important questions of accurate measurement and convenient and scientific nomenclature in a favorable form for the attainment of valuable results.

Whether this Society, as such, shall continue to be known as actively interested in this reform, it is for you not me to say; though I sincerely hope that the members will unanimously agree with me in judging that it ought to do all that its influence, without dictation, can do in this direction. But I for one do not deem the decisions of Societies or other corporate bodies decisive and final. I am not much elated by their approval, or discouraged by their opposition. I have an average amount of respect for the motives but not for the efficiency of legislation. In State, in Church, in Science, it is possible and easy to carry out laws about in proportion as they are unnecessary. People who do not need government are easily governed. Persons who appreciate authenticated micrometers will use them if they can with or without the approval of societies; and those who do not desire them will be about as little controlled by official decisions. While the encouragement and support of Societies and of officials is welcome and valuable as far as it extends, I have more faith in the power of individual influence, and to that I look for an example which is able to settle this question beyond appeal.

In our micrometry we have the anomaly of a system of work capable of a precision almost if not quite unknown elsewhere to human art, for what other wholly artificial procedure posseses a demonstrated limit of accuracy inside of the

1-300,000th of an inch, and yet, until now, we have made no reasonable effort to free ourselves from avoidable errors known to be many times larger than that amount. While coal at $4.00 a ton and muslin at six cents a yard are, or at least pretend to be, measured with apparatus that has been carefully verified by standards of known quality, we have been measuring spaces almost infinitessimally small by standards of only commercial quality and possessed of manifest and uncorrected errors. This fact is too suggestive of the days when micrometers consisted of grains of sand and clippings of wire; with the odds against us that we know how to do better. Arrange your microscope so that it will magnify 3,000 or 4,000 times, making the one-thousandth of an inch on the stage seem three or four inches long through the lenses, then arrange an ocular micrometer so that the magnified one-thousandth of an inch shall be covered by, for instance, one hundred divisions of the ocular scale, and finally ascertain exactly how many of the one-thousandths of an inch on that or any other plate will be similarly measured by precisely the same one hundred divisions above it. Judging from my experience and from that of others who have tried the experiment, you will probably find a perfectly measurable discrepency between the different spaces of the same name; so that even your own measurements, with the same apparatus, will not be comparable with each other unless, as is often done, you select some one average space as a basis of comparison, and are careful to use only that. Now we are trying to ascertain which of these various spaces is the correct one; or if not one is right, then to obtain one that shall be; or if that can not be done, at least to determine a known error from which we can compute definite results. This is not a question of makers, or dealers, or trade interests in any form, but of unmixed and independent science. We are attempting to procure a standard because we need it, and we hope for the cordial assistance of microscopists of really scientific spirit in the difficult work of attaining it, and in the almost equally important task of bringing it into general and respected use. I call this a standard for convenience, and not in a strict or ultimate sense. Strictly it is only an authenticated copy of a standard, or a portion of a standard, namely, of the world's standard meter or standard yard; and hence, the importance, not fully shared by the original meter itself, of its corresponding perfectly with its theoretical length.

The adoption of the metric system has a formal sound, and its difficulties have been, to say the least, well represented. But, to the extent of its use in micrometry, it really presents no difficulties and many advantages. The value of the millimeter and its decimals must be made familiar to the mind for other purposes, even for the understanding of exclusively English literature, and to use it for our measurements and statements will merely assist to keep it fresh in mind. The English system, or rather tradition, presents no pair of units so convenient for the microscopist as the millimeter for large objects and the 1-1000th millimeter for small ones. For the purposes of most people, for use in micrometry alone, it is sufficient to remember that the millimeter is about one twenty-fifth of an inch, and surely that is no great intellectual task. Nor would it waste a large portion of a lifetime to learn the whole series from the meter down, remembering that, in round numbers, the meter is a yard, with three or four inches to spare, the decimeter one-tenth of that 40 inches, or 4 inches, the centimeter one-hundredth of that 40 inches, or 4-10ths of an inch, and the millimeter one-thousandth of that 40 inches, or 4-100ths, or 1-25th of an inch. The real difficulty lies, I believe, not in memorizing the value of the few new units required, but in the awkward and useless

habit of stopping to translate every item from the new unit to an old one. Any one can add a few new words to his vocabulary, a few new units to his tables, without harm. The telephone and the phonograph have brought no disaster along with their new double Greek names. An educated person can learn in an hour all the new terms, values and proportions of the whole metric system, with its interesting and suggestive relations; and the time would be well spent though he never used the system again. But I know by experience that he can also use it again, easily. When you once learn by a little practice to think in the new units the same as in the old, the apprehended difficulties vanish unaccountably and can scarcely be brought to mind again. If asked to estimate the width of this room in yards, only a child unfamiliar as yet with the practical use of measures would say to himself, "It seems to be about 90 feet, which would be 30 yards." You would, rather look at the wall to see how many times longer than a yard it is. So if you will take a metric rule, learn well how the millimeter looks, and its dek, the centimeter, and learn to use it in measuring and estimating the size of suitable objects, such as insects or flowers, you will find it as easy to think in millimeters as in lines, inches, feet, or yards, to say nothing of the comfort of knowing that you are in no danger of being lost between several kinds of the same name.

Aside from the selfish though sufficient motive of our convenience, I hope we shall practically adopt the metric system, because we can thus contribute a trifle of influence toward its general introduction. It seems plain enough now that our country made a serious mistake in not adopting it at first; and I am satisfied that it is still best for us to use it, notwithstanding the greatly increased difficulties in our way. It is not questioned that this is the best system ever tried or proposed, and the only one that can possibly come into general use; it is not denied that it would simplify education, and substitute order and intelligible relations for the confusion of our present metrology; it possesses as many points of convenient relationship to our old system as could reasonably be expected in any new one; it is admitted to be excellently adapted to all scientific work; it has been satisfactory to mechanics and manufacturers who have actually used it; it has been gradually and completely introduced into large shops using costly tools and machinery, without serious expense, and to the satisfaction of the managers. Almost without exception its friends are those who have used it, and objections to it come from those who have not. You hear less of the evils it has caused, than of those it would cause. Furthermore, it offers us a carefully elaborated scheme of international co-operation, which we have but to adopt in order to place ourselves in harmony with the rest; the metric system is all international. It also unifies almost entirely the records made by persons adopting different units, since a statement of size will be practically the same to the eye and to the ear, and will require no formal mathematical reduction, whether made in centimeters, millimeters, or in decimals of a millimeter. Fortunately we have all tried the experiment for ourselves, in one department, and know what some of the objections are worth. Our system of currency is precisely like the metric series of weights and measures; and is marked essentially by the same evils and benefits. Who now believes that having adopted a currency incompatible with the English system has caused us a hundredth part of the trouble it has saved, notwithstanding that it lacked the advantage of putting us in harmony with the rest of the world? Who now feels cut off from the past because of the change, or regrets the loss of the pounds and shillings so long as he has dollars enough, and of the right kind (it is not easy to satisfy

everybody about that)? Who has found the poor oppressed and the laboring classes annoyed by the system we adopted? Who has yet incurred a burdensome expense in hiring accountants skilled in a foreign and to us obsolete nomenclature to compute from the records of the past how many pounds, shillings and pence, our grandmothers paid for their bonnets, or our grandfathers for their ships or their farms? The truth is the new system is so much better for our present purposes that we are glad to use it as soon as we fairly know how; and I believe that the same would be true of the whole metric system. We do not undervalue the records of the past, with their elaborate computations, and tables, and surveys; but few of the people of to-day come in contact with these directly, and those few could afford the extra trouble for the sake of the far greater interests involved. It is not scholars to whom learning in an unfamiliar form is a terror; they will spend lifetimes in working over such lore, merely for the pleasure of the work. And so much of it as is required for use in the daily life of the illiterate world is constantly modified, and modernized, and adapted, by specialists of various kinds, who inherit the progress of the past but adopt the fashions of the present.

To adapt a homely phrase which has remarkably vindicated itself, in another field, in recent history the proper way to introduce the metric system is to introduce it; not to decide why others should use it, but to use it ourselves. Nor need we wait to be certain of the feasibility of securing its universal use. It may be profitably used in science though not accepted in trade. The chemists have adopted it fully and with satisfaction in their work, in their teachings and in their books; the physicians are adopting it in different parts of the country, and the microscopists may well enjoy its facilities whether others do so or not.

The most important suggestion to be made in respect to the *use* of the microscope is—not to forget to use it. The instrument itself is brilliant and attractive, and a refined taste and cultivated appreciation of the beautiful may well derive pleasure from familiarity with its exquisite brass-work and its subtle optical refinements. But the love of the instrument is liable to make us forget that it is partly a tool and not wholly a toy. Unless intelligently careful to avoid it, we may fall into the folly of becoming men of magnificent preparations, but unimportant results; of forever getting ready to do nothing; of accumulating a vast quantity of exquisite material, which shall be lost to the world as soon as we possess it. An illustration from a less familiar object, not associated with our own habits and possibly with our own mistakes, will best explain this difficulty which is at the bottom of nearly all the prejudice that really exists against our specialty, and which has led some perhaps too hasty critics to object to the very name of microscopist. Suppose a person to become fascinated with the ingenious construction of a nut-cracker. He likes the kernels that are hidden in the nut-shells, but is far more pleased with the method of getting them out. He studies up the transmissions and resolutions of forces by which the power of his hand is applied to the useful purpose of disintegrating the stony pericarp of the tempting fruit. He knows the qualities, the advantages and disadvantages of the different material used in constructing the crackers. He can tell, to a day, when the different styles were invented and patented, and by whom. He has the merits and faults of every maker at his finger ends, and he knows whose style of manufacture is best adapted to every kind of nut. He has a faultless collection of nut-crackers, and of nuts to try them on; possesses nut-crackers of brass and iron, of bronze and of steel, and possibly one of solid silver; has them furnished with handles of mahogany and

rosewood and maple, and covered with leather or clóth, or not at all, as the most discriminating judgment should dictate, and finished in every style known to art. But with all this preparation, he never cracks any nuts, unless incidentally and for the sake of showing how the machines work. A child with a hammer and a stone, and a sharp appetite for meats, might teach sages a lesson here. Of course, somebody must devise improvements to the apparatus if they are to be made at all; but this devotion to the instrument, as such, is more likely to be overdone than neglected. Yet I would not, even by implication or omission, disparage the use of this instrument as a mere recreation. I am a strong believer in the value of amusement, and in its importance to individuals somewhat in proportion to the weight of the responsibilities of their more serious life; and I know not of a more worthy toy for the entertainment of a thoughtful person than the microscope. Many of the most cultivated and distinguished men use it as a recreation, and do well; but they are intellectual and scientific spirits who use it as a toy; they are not either intellectual or scientific because they so use it. It would save a vast amount of waste of energy and loss of opportunity if there were a clear appreciation of the difference between microscopy as a play and microscopy as a science. It is most common and most desirable to combine the two, provided we are not thereby misled.

What may be called the scientific uses of the microscope were earlier cultivated, and have become more fully developed and appreciated than its practical ones. The instrument had revolutionized the sciences of Zoology and Botany, and made great contributions to palæontology before its application to the practical needs of civilization had been fairly attempted. Nor is it to be regretted that the higher and more noble field was occupied first and received the most and best work.

But lately the *practical* applications have been made prominent, and they constitute a field attractive, comparatively little worked, and where labor that is original and really valuable is certain to be appreciated. The study of fabrics and the different articles of commerce, their various qualities, adulterations and substitutions, is a field as fresh as it seems to be preoccupied. The exhaustive work of Hassall, which would be discouraging if recent, does not apply to existing facts, and the work of to-day is still to be done; and it surely needs to be done when adulterants are adulterated at wholesale, and microscopic specimens themselves falsified for the purposes of trade. The interest sure to attach to such work may be inferred from the attention commanded by recent discussions in regard to the discrimination of wool, and the distinguishing of butter from oleomargarine which is not essentially a fraud and only becomes so when bought without a knowledge of its character. The sanitary and medical uses, in the investigation of water-supply, the purity and excellence of food and medicines, the accurate discrimination of diseases, the causes and laws of contagion (including that well urged but still disputed germ-theory of disease), are still more important themes, which, though comparatively familiar, still offer numerous vital points for completion or reconsideration. The usefulness of the lenses, in war as well as peace, has been permanently established; the pigeon post of Paris during the siege having taught a lesson how the isolation of an invested city may be broken by their means.

The *legal* uses of the microscope offer a department so large that it might almost be regarded as a new science, under the name of Microscopical Jurisprudence; and a few suggestions in regard to that subject will occupy the remainder

of this address. Some of its details, as for example the discrimination of blood and other important varieties of stains, have been treated, and conveniently, under medical jurisprudence, though they are not medical to any extent, and though they belong properly here. Others are entirely new and are appropriately, and I understand in the opinion of the courts, just as properly objects of judicial consideration as are the so called medical portions.

The importance, in this respect, to humanity, of chemical, physiological, pathological, and microscopical learning and skill, can best be appreciated by reflecting upon the means which modern science and art have furnished for successfully violating the rights of fellowmen, and for escaping from the consequences of such acts. With the telegraph, the popularized press, and the railway at command, it sometimes seems, notwithstanding the counter effect of these agencies in bringing criminals to justice, as if well-planned crime might be committed with impunity, and society lose so much of its safety as is derived from the fear of punishment. But at this point science appears with still more subtle means of discrimination, and the balance is yet preserved on the side of right.

The admission of the facts and opinions presented by scientific men as a proper means of influence in judicial procedures, or in other words a general admission of expert evidence, having but recently become an important agency, and one that seems likely to grow in power if managed strictly in the interests of truth and science, it is essential that men of science before falling into possible errors, should clearly establish and agree upon those principles of action which shall guide them in such cases. The spirit of science is that of truth, not partizanship. The facts and opinions of science should be developed with absolute impartiality. They should be given fully and freely, whether apparently favorable or unfavorable to the person for whom they are prepared.

The scientist should allow his name and influence to be used only when the full bearing of his statements, in spirit and in probable effect, and without qualification or reserve, is exactly what it purports and seems to be. Nor should he allow his aid to be used to the detriment, in his judgment, of honest individual or social interests. I am aware of the difficulty of this position; he can not hope to judge correctly every case in advance, which even the members of the legal profession do not claim ability to do, but he should in my opinion limit his influence to those cases where the facts within his cognizance seem to fully, not partially uphold his action, and where they do not seem likely to be used in the accomplishment of wrong. Fortunately he is under no compulsion of usage or the necessities of society to act in any case against his own convictions. The custom of defending, so far as practicable, almost every cause, however undesirable its success might be, although apparently unavoidable, is in the judgment of those outside of the profession best qualified to decide, the least satisfactory point in the relations of present legal usages to the interests of society; a point at which no doubt all honorable members of the profession take the greatest care to prevent their personal success and that of their clients from becoming a hardship to others; where persons without character who are liable to creep into any profession without becoming assimilated to it, find it easiest for selfish purposes and with impunity, to make themselves the enemies instead of the friends and the protectors of society. The scientific expert should be, in his limited sphere, as impartial as a judge; and he should appear in no cause where that policy would be unwelcome. It might be supposed that such a course, if deserving no credit, which it does not claim, would at least protect from detraction

or insult; but it will not. It will be respected, I believe, by courts and by counselors of respectability and influence, and it is to be hoped that some means may be found by which it can be protected also; but at present it must expect sometimes to sustain itself against disparagement and insult from some person who may have acquired the place without the character of a counsellor, who is none too honest to excite ignorant prejudice against notorious truth by the use of sneers and derision, none too generous to meet simple statements of facts with the merely brutal force of overbearing manners, none too brave to insult a person who is in his power, and none too well bred to bring into the presence of gentlemen, of honorable counsellors, and of dignified judges, the methods, the manners and morals of a coarser civilization. If, as I have been assured by eminent members, the legal profession regards its incompatible and unworthy adherents with the aversion shown by other professions to theirs, it is not too much to hope that it may soon set a standard for itself which will practically command the obedience of all.

The examination of hand-writing, with a view to determine its authorship, its genuineness, its age, and whether or not it has been altered from its original form and intent, is one of the more recent uses of our microscope, and one the importance, reliability, and frequent applicability of which has but recently become known, and is even now not generally realized. Perhaps this is to be accounted for by the fact that large general experience, judgment, and tact in the use of the instrument, and skill in the manipulation, though necessary to this particular work, are not, in themselves, an adequate preparation for it. Much special study, and special practice, is required before anything useful can be done, or important should be attempted. But to a person really at home in the study of hand-writing, both with and without the microscope, this instrument furnishes a ready means for its accurate analysis. Those who are governed, not by respect for the rights of others, but only by the expectation of consequences that shall affect themselves, can not learn too soon, or too well, the fact that writing can scarcely be changed, after its original execution, so adroitly that the microscope can not detect the falsification. The face of the paper when once marred, by disturbing the position of the fibres, can never be restored; and hence scratching and erasure can be recognized though performed with consummate skill, and not distinguishable by other means. Inks which are alike to the unaided eye, are marked under the lenses by conspicuous differences of shade or color, or density, or purity, or chemical composition. Lines which look simple and honest, may show themselves as retouched, or altered, by the same or by different hand or pen or ink; and lines drawn upon new paper may look different from those drawn after it is old. The microscope does not give any direct information as to the precise age of writing, but if used with sufficient caution it can determine (not so easy or safe a task as might be supposed) the relative age of superposed, crossing, or touching lines; and it can generally state positively whether lines were written before or after related erasures or scratchings, or foldings or crumplings of the paper. In one important case, my friend, Mr. Wm. E. Hagan, of Troy, who has given extensive and very successful attention to the study of writing, especially imitative writing, and in association with whom many of my own investigations in this field during the last dozen years have been carried on, established the date of a document by recognizing in the paper fibres which had only recently been used in paper-making, and which, in connection with corroborative proofs to which they led, demonstrated that the paper was manufactured at a later date than that claimed by the writing upon it.

To discuss the subject of imitative writing would require the opportunities of a book, and not of a fraction of a lecture; and many considerations of recognized importance connected with it are still under investigation and not sufficiently mature for publication. A few hints may be given in respect to those points which are well established and most generally applicable. When a word, in a fictitious signature, for instance, has been constructed by tracing it with pencil lines over an original one, and subsequently inking it over with a pen, particles of plumbago can probably be somewhere detected and recognized by their position and their well-known color and lustre. The mechanical effect of the point of a pencil upon and among the fibres of the paper can also be seen, notwithstanding the subsequent staining of the paper by the ink. This clumsy method of copying carries its own means of detection; and still it is not more easily recognized than are methods that are more subtle and seem more dangerous. In writing copied or imitated originally in ink, either by tracing it over a copy or by drawing it free-hand with a copy to inspect or to remember, the distribution of ink is peculiar and suggestive, indicating hesitation, from uncertainty, or pauses to look at a copy, or to recall a style or to decide as to a future course, just at points where a person writing automatically, by his own method, and especially in writing his own name or a scarcely less familiar business formula, would pass over the paper most rapidly and promptly. Again, there are certain ear-marks, results of habit, which finally become as natural as it is to breathe, and which characterize the writing of different individuals. Such are peculiar forms and styles of letters and of combinations of letters; methods of beginning or of ending lines, letters, words or sentences; methods and places of shading, or breaking lines, and of dotting, crossing, patching or correcting; habits of correcting or not correcting certain errors or omissions; the use of flourishes; and peculiar ways of connecting words or of dissociating syllables. In imitative writing these ear-marks of another ownership are generally copied with ostentatious prominence, if not with real exaggeration, in the capital letters and other prominent parts, but lost sight of in those less conspicuous places where imitation naturally becomes feeble and the habit of the writer unconsciously asserts itself; and this revelation often becomes more positive by reason of the elaborate efforts that are made to suppress it. Things are overdone from fear, which would have been negligently done from habit; not to speak of gross blunders proceeding from the same source. I once examined a disputed signature from which had been carefully scratched out a line, immaterial and inconspicuous, which conformed to the habit of another person interested in the case, but not to the habit of the ostensible author of the writing. Furthermore the genuineness of a writing may often be disproved by the very success with which it followed its copy, reproducing its mistakes, idiosyncracies, or its adaptions to its own special sorroundings; in which respects it may correspond too accurately with some one genuine signature (in the hands, for instance, of a suspected person) but differ unquestionably from the ordinary habit of the reputed author. Modifications of style by disease, as paralysis, may present similarly decisive discrepancies or coincidences. There is a peculiar tremor, too, about the writing of an individual, which is dependent on the physical conformation of the writer as related to his habits of position, touch and motion, which is quite characteristic, as it can be neither imitated nor concealed. All these investigations in respect to writing can be best pursued with the aid of the microscope, and some of them are entirely dependent upon it. For general view of the words a four or three

inch objective is best adapted; for special study of the letters a 1½ inch; and for minute investigation of the nature of the lines or character of the ink a ⅜ds or 4-10ths. The lenses except the last should be of the largest angles ordinarily made, and all should be of flat field and of the best possible definition. The microscope stand should have a large, flat stage; though it is generally preferable to use a small portable stand which can be moved freely over the paper and focused upon it at any point without the use of a stage. For this purpose I sometimes use a tank microscope, but more frequently a pocket microscope with its tube prolonged through the stage by adapters, so that it focuses directly upon the table. Even so large an instrument as Zentmayer's histological, may be so used to advantage, though a lighter form and smaller size is far more convenient and sufficiently steady for this work. A medium-sized bull's eye is sufficient for the purpose of illumination; and good judgment is more important than, if not incompatible with, the employment of an ostentatious and unnecessarily elaborate apparatus.

To illustrate the application of the microscope to the critical study of writing in cases of practical importance, and its dependence for much of its value on the appreciative comparison of related facts, I will describe a single and very simple case of altered writing occurring many years ago. A certain note, admitted to be genuine and properly signed, and upon which a considerable amount of money and a far greater value of character depended, bore date of the sixteenth of a certain month. The number of the year was printed on the blank except a single figure, 1, which was filled in with writing ink; there was also a figure 1 written below in the body of the note. The last-named 1 was lightly and smoothly written, of such size and color and style, as might well have been written at the same time and by the same person as the rest of the note. But the figures 16 and 1 of the date were written clumsily, twice as large as the other, with a pen of different properties and with ink of different color and density. This peculiarity of these three digits was well explained by the claim, supported by the most plausible circumstantial evidence, that the date had been left blank at the time of drawing up the note, and had been filled in at the time at which it was subsequently signed, and with writing materials whose character sufficiently accounted for the nature of the figures. One person, who was largely interested in the note having been signed earlier than the date upon its face, and who well knew whether or not it was originally dated upon that day, asserted that its original date was several days earlier than that, though he did not fix it upon any one particular day. Another person who was admitted to have written the date, who had enjoyed unlimited opportunities for changing it if he desired, and was largely interested in its bearing a date not earlier than its ostensible one, asserted that that was its original and only date. At first sight, and still more after much patient study, it seemed hopeless to expect a solution of the case through the microscope or by any other means. The tracks of crime, if present, were never more carefully covered. The disputed figures were bold and strongly characterized. They showed no attempt to make them look like the rest of the writing, and therefore suffered nothing from failure to accomplish it; and their well marked character was satisfactorily accounted for. The surface of the paper was microscopically perfect, and had not been tampered with for purposes of erasure. Nowhere did a line crop out into view like those of the rest of the writing; and if any such existed beneath the visible figures it was doubtless pale and thin and little likely to be perceptible, even to the microscope, through the heavy coating of thick and muddy ink which covered and concealed it. At last by one

peculiar illumination, light being diffused rather faintly over the top of the paper and at the same time condensed strongly upon the lower surface, there came into view an appearance which was lost by the least change of illumination, but could be restored again by careful arrangement of the light. Blended with each of the three disputed figures, though not equally distinct in all, was a very peculiar wedge-shaped or triangular figure, broad and flat at the top and sharp at the bottom, and exactly such in size and position as would accord well with the rest of the writing and with the other figure 1 in the body of the note; but the latter 1 was broad and square at the bottom, and thus strikingly unlike the wedge-shaped 1's. Comparison of a large number of papers known to have been written by the same author showed that the unusually triangular 1 was his characteristic style, and that the unaltered and not triangular 1 in the note, known to be his writing, was not his usual habit but a rare and, as it proved in this case, a puzzling eccentricity. It was evident that the date had been first written 11, and that the 16 had been subsequently written over it; and that the 1 of the year, though the right figure, had been similarly enlarged to make it look like the rest. (Figures shown on blackboard.)

Still newer but scarcely less important than this is the study of powder marks, which call for investigation with the microscope less frequently, it is true, but are likely to be connected with results of the highest interest. Fixing the responsibility of a fatal crime, involving capital consequences, may turn critically upon such questions as the time of firing a certain shot, the position from which it was fired, the kind of powder used or the nature of the weapon employed, all of which questions under certain favorable but not improbable circumstances may be positively answered by our instrument. It is well known that modern gunpowder is not a powder at all, but consists of hard and well-formed grains, often of considerable size, which by burning gradually and comparatively slowly from their surface only, gradually crowd the ball into increasing velocity as it moves through the barrel toward the mouth of the gun, and finally eject it at a speed and with a power that could not be safely attained or even approached by a fine powder that would burn more rapidly and communicate its impulse more suddenly, and perhaps with destructive force to both ball and barrel. But before the grains are fully burned, the rapidly decreasing advantage gained in this way becomes more than counterbalanced by the resistance to the ball by continued contact with the barrel. Therefore the barrel is never made long enough for the powder to wholly burn before leaving it, and some of the burning grains must in all cases be thrown out as projectiles along with the ball. In using large charges and coarse powder some grains also may be thrown out that have not been ignited at all. The shorter the barrel, other things being equal, the more will this happen; as it will, also, in the case of the pistol, where the charge is generally less than in the rifle, but the flash is greater because the barrel is shortened more than the charge is diminished. To observe the course of these burning grains to advantage, cause a pistol charged with coarse powder to be fired in the dark at a distance of a few meters and at right angles to your line of vision, and the tiny projectiles will be seen to describe graceful curves, each one mimicing within the range of two or three meters the trajectory of the leaden bullet in a course five hundred times as long. If the shot be fired through glass at a distance of one or two meters, the ball will pass through leaving a hole that will vary somewhat in appearance according to circumstances, and the burning powder grains will leave, where they strike the glass, pale, grayish stains which

look somewhat like grease spots, or like the fungoid specks where diseased flies have adhered to the glass in autumn. They may be recognized, however, by their grouping around the bullet hole, by their microscopical appearance, and by chemical analysis, since they do not behave like grease in the presence of suitable tests; and Mr. Hagan has repeatedly obtained from them the sulphurous reaction of blackening a microscopic quantity of a salt of lead.* Being caused by the burning powder grains, they indicate with certainty that the shot was fired near the surface; and a further hint as to the distance may sometimes be obtained from the degree of lateral or vertical displacement of the whole cluster as measured from the position of the ball-hole, the trajectory of the grains being considerably modified, and that of the ball not perceptibly so at such distances by gravity, or by a strong lateral wind. Still more interesting and suggestive are the appearances when the grains are fired against wood, paint, clothing or the human face; the latter experiment being often tried by small boys who look into the touch-hole of a small cannon on the Fourth of July, to see whether the cannon is going off or not, and with the familiar result of being so well satisfied of the fact that they can prove it any time thereafter. In such a case the burning grains may scorch and smut the surface, and the whole grains may bury themselves entirely below the surface, from beneath which they can readily be dug out, still in a condition capable of exploding. If the grains be small or positive identification be required, by keeping the grain distinctly in view during the manipulation, it should be performed only under the microscope. How small a quantity can be thus treated may become an important question. Every intelligent person at all informed as to microscopical manipulation knows that an object of which it would require thousands to weigh a grain can with perfect ease and certainty be manipulated, examined, preserved and re-examined by any person of ordinary skill and ample experience in such work. To determine whether minute particles of powder could be not only seen and handled but also burned with characteristic results, and finding it inconvenient to weigh such minute quantities, I procured one decigram (1-½ grains) of powder, carefully weighed and found it to contain by actual count, one hundred and fifty-three particles. Several of them, of average size, were selected, each of them being by estimate about the 1-100th of a grain in weight. One of these particles, tested by being placed on a strip of platinum foil, covered loosely with a cover-glass, and gradually heated over a spirit lamp till it burns, will explode with a distinct flash and an audible sound, both flash and sound being perceptible to several persons at once in distant parts of a small room. Similar results, though less in degree, were obtained from smaller quantities, estimated to be one-tenth as large, or 1-1000th grain. The experiment should be tried in a partially darkened room, but still so light that the black particle can be distinctly seen and its identity assured until it explodes. A cloudy, grayish stain is left upon the under surface of the cover-glass, whose appearance is distinctly suggestive of the flash. As there is usually no difficulty in digging out grains as large as those I have mentioned, this test may be said to be applicable to all cases where unaltered powder can be found imbedded. In this manner have been identified as powder, black particles taken from spots which had previously been characterized as pencil marks, and which if powder would absolutely prove a shot to have been fired from a position different from that which was understood to be implied in the theory of the prosecution. Examined under the microscope while still, and recently, imbedded in some dry substance, the powder

* They may be interspersed with real grease spots caused by the lubricant from the bullet.

grains appear to be dry and dark, and granular; and their size may often be so fully determined as to indicate positively to which of two different kinds of powder they belong. After being repeatedly or persistently moistened, they become brownish, and spongy in appearance, and may be surrounded by an efflorescence of nitre which is very characteristic. In some cases they become surrounded by a blueish ring on the white paint they have penetrated, believed to be produced by a reaction between the sulphur of the powder and the lead of the paint. Usually some of the grains only indent the film of paint, or the weather-hardened face of the wood, without imbedding themselves; and this may be true of all if the grains be small, the distance great, or the charge light. At a medium distance, the largest globular grains may imbed themselves fully, while the flat, lenticular grains, if they strike upon their flat side, will only indent the wood, but if they strike edgewise will cut partially into the fibres if crossing their direction, but bury themselvs deeply between them if they strike with a cutting edge in the direction of their length. In these various ways may suggestions be gained as to the kind of powder and weapon used, the weight of the charge, the distance fired, the time that has elapsed, and the treatment to which the surface may have been subjected by nature, by accident, or by design. Further light may be obtained from the character of the hole made by the ball in passing through the glass; but this is independent of microscopical aid.

These hints concerning some of the fresher fields of microscopical study, show that it is timely as well as fascinating, practical as well as scientific. We pursue it at a favorable time. Never before was the microscope as serviceable an instrument as at present; never before were good microscopes so plenty and so cheap, or cheap microscopes half so good; never, perhaps, were more important fields for work fully open and recognized but yet unoccupied. We shall do poor work, indeed, if we do not make the microscope not only a source of pleasure to ourselves, but of more serious profit to science and to humanity.